DETAILING BASEMENT WATERPROOFING

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Abstract

Waterproofing details that are prepared for below-grade projects by the architect or waterproofing consultant typically indicate horizontal/vertical transitions and pipes/conduits that penetrate through the foundation or at sump pits. However, there are conditions that—if left solely to the contractor or addressed hastily in the field—can cause problems that are difficult and expensive to correct or remediate.

More often than not, details that are critical due to the requirements of the support of excavation (SOE) are frequently omitted by the designer because he often fails to review them or is unaware of the fact that such drawings actually exist.

Waterproofing designers need to be aware that these conditions exist and must make provisions for providing proper membrane terminations where they occur.

Speakers

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ABSTRACT

Waterproofing designers, more often than not, prepare their details based on the structural, architectural, and MEP drawings without reviewing the support-of-excavation drawings. These often contain members that encroach on the membrane and require special treatment to ensure that the waterproofing maintains its watertight integrity. Raker foot blocks penetrate underslab membrane, tiebacks protrude into the foundation wall, and walers are left in place and must be flashed into the system. Not all of these are indicated on shop drawings. This paper reviews many of these conditions. Failure to address them can result in a blizzard of requests for information (RFIs), extras, or a leaking basement.

INTRODUCTION

Among the most overlooked details of below-grade waterproofing are those that illustrate membrane penetrations and terminations. Although many manufacturers devote a number of pages in their literature to typical details that are generally encountered on most projects, they often fail to address special conditions that are required by the earth-retaining system installed to support and protect the excavation. The components of the system are indicated on drawings that are usually prepared by the excavator to illustrate the methods by which he intends to support the excavation during the construction of the basement. These are called support-of-excavation or SOE drawings. Sometimes the drawings are prepared by the project foundation structural engineer with input from the geotechnical engineer; but often they are considered to be “means and methods” and are assigned to the excavation contractor’s engineers. It is the waterproofing designers’ responsibility to obtain these drawings in order to prepare details that address each penetration and termination. Failure to do so may result in a blizzard of RFIs and extras after the waterproofing contract is awarded. However, even if preliminary SOEs are prepared by the foundation engineer, cost increases and design changes can be expected after the final documents are submitted by the excavation contractor.

Basements subject to hydrostatic pressure, whether from rainfall or an existing water table above the basement floor slabs, are waterproofed by membranes either pre-applied to the earth-retaining system using one-sided forms or post-applied to the foundation after it is erected, using two-sided forms. The latter requires that the walls of the excavation be far enough outside of the building line to enable the applicators to install the membrane, usually not less than 30 inches (750 mm).

The membranes discussed in this paper are those that are fluid-applied or applied in sheets and those that are bonded to the concrete components. Bentonite-based and most unreinforced fluid-applied membranes are not included, although many of the conditions discussed herein are similar.

BASEMENT CONSTRUCTION

There are many different methods of supporting the excavation when the basement is constructed in urban areas with tight, restricted spaces and not just simply installed in open excavations and backfilled. The earth-retaining systems can be used solely to support the earth and act as deep-water cutoff walls or additionally be designed as structural foundation walls to support the building above.

For the purposes of this paper, a basement is defined as a habitable space enclosed by foundation walls that retain earth. Where the water table cannot be maintained at least 6 in. below the bottom of the lowest floor on-ground, the International Building Code requires basements to be waterproofed. Waterproofed basements are constructed of concrete or reinforced masonry walls designed to withstand the pressure of the earth and water, and slabs-on-grade designed to resist uplift pressure created by the buoyancy of the water.

Basements can be constructed by two methods:

- **Bottom-up construction**: With this method of construction, the earth enclosed by the foundation wall is excavated, the walls braced, and the pressure slab cast on grade.
- **Top-down construction**: With this method, the foundation and interior columns are cast in trenches or holes drilled in the earth, the first-floor slab is cast on the grade at the ground level, and the soil removed below it. If required, the foundation is braced with cross-lot blocking or rakers and walers as the earth is excavated below the slab, exposing the foundation wall. Intermediate floor slabs are cast as the earth is excavated, eliminating the need for bracing.

Bottom-up is the most common form of construction and requires that the walls that support the excavation be braced either internally by structural members or tied back into the surrounding earth.

Earth Retention Systems

Earth retention systems are not standardized within the United States or in a particular state. They are typically custom systems, depending on the local experience of the contractor, site conditions, availability and cost of materials, and the amount of shoring that may be required.

These systems may be designed to both support the excavation and serve as the foundation wall or only to support the excavation and minimize the inward flow of groundwater. In the latter system, the components are socketed into the earth or rock to create a dam.

Common earth-retention systems are:

- **Sheet piles** of profiled steel. Sheet piling was patented in the 1890s.
and began production in the early 1900s. Sheet piling is manufactured from rolled steel and can be purchased in various shapes. Sheets are interlocked in a number of ways in an attempt to limit the passage of water and soil particles.

- **Trench boxes** are steel fabrications that are installed into the trench and dragged along with the excavation. The walls are constructed from sheet steel and braced apart with steel tubes. The box protects workers in the trench and the work under construction that could be damaged from collapse.

- **Soldier piles and lagging.** This is the most common shoring solution in urban areas. Piles are vertical, H-shaped structural sections or pipes closely spaced with wood members connected to them as the earth is removed.

- **Secant piles** are cast-in-place concrete in drilled holes designed as interlocking tubes or cylinders. Every second tube or cylinder is reinforced with a wide-flanged steel section or, alternately, with a reinforcing steel cage. The inboard faces can be cut back to the face of the steel pile flanges, or a concrete or sand wall installed over them. The reinforced piles are called "primary" piles, and the intervening piles, "secondary" piles.

- **Drilled/concrete soldier piles.** These are drilled steel tubular piles that are to be filled with concrete. The cylinders are closely spaced, and shotcrete or sand walls are installed on the inboard faces to provide a smooth substrate to receive the waterproofing.

- **Slurry or diaphragm walls** are constructed of bentonite/cement for cutoff walls or cast-in-place concrete for structural walls as panels with interlocking ends that may incorporate waterstops. They can serve a dual purpose of shoring the site during excavation and acting as a permanent wall once construction is complete.

- **Precast concrete panels** installed in excavated trenches.

- **Soil nailing/shotcrete.** Soil nailing consists of inserting slender reinforcing elements into the soil. The reinforcing is installed into predrilled holes and then grouted. Shotcrete (pneumatically applied concrete) is then applied over the surface to act as a rigid facing. The terms "soil nails," "rock anchors," "soil anchors," and "tiebacks" are sometimes used interchangeably.

Sometimes several earth retention systems may be used in the same excavation.

**COMPONENTS OF EARTH-RETAINING SYSTEMS REQUIRING SPECIAL DETAILING**

Some components require details that are fundamental to all projects but are not discussed in this paper. These include:

- Membrane transitions between pressure slab and foundation walls
- Transitions between underslab membrane and pits
- Terminations at the top of foundations and grade beams
- Transitions between preapplied and postapplied membranes

With the exception of top-down basement construction, components of the earth-retaining system require bracing to resist earth and water pressures. Generally, these are temporary and are removed during the construction of the basement walls. The components of the bracing systems almost always penetrate the membrane and require special details to maintain their watertight integrity.
TYPICAL EARTH-RETENTION BRACING SYSTEMS

Tiebacks or Soil Nails

Tiebacks are rods or a bundle of strands that are placed in cored holes outboard of the foundation. The end that is buried in the earth is grouted into place. The tie is connected to an angle that spans between soldier piles, welded to sheet piling or to bearing plates cast into slurry walls.

Ties are usually left in place after the building is completed. Care must be used in installing ties when there are utilities outboard of the foundation or adjoining buildings.

The inboard end of the strand ties is jacked to provide the requisite tension and secured to head plates.

The ends of rods are also jacked and secured with nuts and washers. Strands and rods projecting beyond the base plate are removed, but the plates, nuts, and washers remain. Since they project through the waterproofing, they must be boxed-in to maintain the watertight integrity of the membrane.

Rakers

Rakers (Figure 1) are structural steel-rolled shapes installed as angled braces with the top secured to the earth-retaining system and the bottom to anchors installed in the pressure slab or, more frequently, to a block of concrete located at or below the pressure slab. This block is called the heel block or foot block and is installed prior to the pressure slab. When the foot block is below the underslab membrane, the raker will penetrate it. The penetration usually is made through a block-out in the pressure slab. Sometimes, the foot block can be incorporated in the pressure slab and the membrane carried under it. After the pressure slab is cast, the raker is burned off at or below the floor level, the waterproofing is patched, and the block-out is filled in.

At the top, the raker is usually connected to an angle spanning between two soldier piles. Sometimes it is connected directly to the face of the soldier pile. If the earth-retaining system is set outboard of the foundation wall, the raker may pass through it in a block-out or connected to a steel brace extending through the wall. Sometimes the raker is connected to a waler.

Rakers are cut off or burned off after the foundation is cast. The heat from torches may melt heat-sensitive membranes, and the removal protocol should be reviewed and discussed at the prewaterproofing meeting.

Walers

Walers are horizontal, wide-flange beams connected to the earth-retaining system that are usually continuous around the basement walls. They are held in position with rakers and diagonal beams at the corners and may also be braced with cross-lot blocking.

Walers may be left in place and buried in the foundation wall (holes are cut to permit the passage of vertical rebars), or burned off or partially burned off where they encroach on the interior face of the finished foundation wall. If the waler is installed on the inside of the earth-retaining system, the structure can be constructed by boxing out around it.

Cross-Lot Blocking

Cross-lot blocking (Figure 2) is accomplished by installing large-diameter pipes that span between opposing foundation walls, often located at the top of the excavation or at every horizontal construction joint. They are welded to the walers and removed after the foundation wall is cast. Brackets that connect the pipes to the earth-retention system may be left in place and cut off at the face of the foundation.

Penetrations

The authors recommend that a single drawing of the points of entry (POE) be prepared for all penetrations through the waterproofed components. These should contain a plan and foundation wall elevations and include all MEP piping with sleeve...
sizes. These penetrations, more often than not, occur at varying elevations through the foundation wall. They may occur at the transition between preapplied and postapplied waterproofing.

There are frequent penetrations through the membranes applied to the pressure slab and the foundation wall. These are not always indicated on the drawings; and some, like well points, may come as a surprise to the designer. All of these require special details.

Most often, water leakage occurs at penetrations. It is desirable, therefore, to minimize them by incorporating pits and piping into the thickened or depressed pressure slab.

**Penetrations Through the Pressure Slab**

Penetrations that frequently occur through the pressure slab include:

- Caissons and pile caps that don’t penetrate the slab, but which interrupt the membrane under it. (Not usually indicated on the contract documents are special foundations for construction cranes.)
- Rock anchors
- Lightning ground rods, as well as the building’s electrical grounding systems
- Well points
- Drains and cleanouts
- Pits such as sumps and elevator pits
- Foot blocks or heel blocks, which have been discussed previously
- Hydraulic elevator pistons

While the basement is under construction and the dewatering system is operational, the weight of the foundation and pressure slab holds it in position. However, when the pumps are turned off, the basement will have a tendency to float or rise vertically. As the superstructure is constructed above, the imposed dead load will cause the basement to settle back down. Where the basement is not constructed on rock, some movement (generally in the range of 1 to 2 inches) should be anticipated. Movement is usually resisted by caissons, pin piles, or rock anchors to secure the pressure slab to the strata below and
either support it or restrain it from floating when the pumps are shut off. Where they penetrate the pressure slab and mud mat, provision must be made to permit differential movement.

Penetrations Through the Foundation Walls

Some penetrations through the foundations are for utilities that require watertight sleeves when they are below the groundwater line. These include:

• Sewer and water pipes
• Conduits for power and electronic cables

Frequently, conduits are ganged, leaving very little space between them for proper flashing. These require precast concrete or heavy-gauge sheet metal manifolds that are sealed to the foundation and flashed to the membrane.

Other penetrations are anchors to tie the foundation back to another wall or to the soil as discussed earlier.

DETAILS

The following details suggest methods by which these components and penetrations of the support-of-excavation systems can be flashed into the membrane and maintain their watertightness. They illustrate general design principles and should be modified for specific waterproofing systems. Keep in mind that waterproofing details are executed prior to installation of the field membrane. Understanding sequencing is critical to properly assembling the flashing components.

Details at Penetrations of the Pressure Slab With Thermoplastic and Modified Bitumen Sheets

Figure 3 shows the waterproofing at the top of a caisson prior to casting the grade beam. Figure 4 shows a typical rock anchor or minipile penetrating the pressure slab. The flashing must be arranged to accommodate movement between the mud mat and the penetration.

Lightning-grounding conductors are usually stranded cables. They cannot be made watertight where they penetrate waterproofing membranes, because water flows between the strands capillarily. A coupling to transition from a stranded cable to a solid rod is required (see Figure 5).

Details at Penetrations of the Foundation Wall With Thermoplastic and Modified-Bitumen Sheets

Figure 6 shows a typical condition where lagging is installed behind soldier...
piles. It is not unusual to find that the lagging has been secured with nails that are bent over the soldier pile flanges. The lagging must be boarded out with plywood, EPS, drainage composites, or a combination thereof.

Figure 7 shows typical pipe penetrations. Single-pipe penetrations are not difficult to solve, but ganged pipes pose a problem. This often occurs at transformer vaults where utility companies dictate the conduit spacing. The pipes or conduits are often so closely spaced that they are impossible to flash in the manner illustrated in the waterproofing manufacturer’s catalogue. The easiest solution is to provide an assembly composed of plates with welded sleeves that can be placed in the form with the edges flashed into the wall. Care must be taken to avoid interrupting the rebar cages and to provide a frame to support the wall construction.

Pipes and conduits are inserted in the sleeves and made watertight with a series of rubber modular seals that are tightened with a wrench to form a watertight seal around the pipe. See Figure 8.

Figure 9 shows a typical tie-back penetration. This may vary depending on whether the tie is a tension rod or cable strands. In either case, the tie will remain in place during the life of the building and must be flashed into the wall waterproofing system. This is usually accomplished by covering the tie with a prefabricated wood or metal box and flashing the box at the perimeter. There are some manufacturers that market factory-fabricated tie-back covers for this detail. The one-size-fits-all covers may not be as flexible as the boxes fabricated by the waterproofing contractor.

Figure 1 (page 106) shows a typical condition where the raker penetrates the pressure slab and underslab waterproofing. If possible, the SOE contractor should be encouraged to eliminate the penetration of the membrane by one of the following:

- Raise the foot block so that the top is above the underslab membrane.
- Depress the mud mat and thicken the pressure slab to absorb the foot block.
- Cast a section of the pressure slab and provide bolted angles to anchor the bottom end of the raker.

Figure 6 – Typical condition where lagging is installed behind soldier piles.

Figure 7 – Typical pipe penetrations.

Figure 8 – Pipes and conduits are inserted and sealed with rubber modular seals.
When these steps are not implemented, the penetration of the bottom of the raker must be flashed into the underslab membrane.

1. The raker is boxed out with metal and the flanges are flashed into the membrane. The void formed by the metal box is then filled with quick-setting grout.
2. Alternately, the raker is flashed to the membrane using tapes and the liquid component of the membrane system.

Walers pose another problem. If they are held off from the earth-retaining system, the stand-offs must be boxed in. The problem when cross-lot blocking or walers are to be removed is to avoid damage to the flashing from the heat of the cutting torch. This requires careful sequencing and, often, repairs, after the steel members are burned off.

Often, the problems can be resolved by staging the backfill or installing upper and lower tiers of rakers and walers. By selectively removing upper and lower tiers and providing interim bracing with berms, the earth-retaining wall is made available to hang the waterproofing. One SOE contractor used the following sequence:

1. Install walers and cross-lot blocking.
2. Excavate to subgrade, leaving required berms against sheeting to allow installation of lower-tier bracing.
3. Pour a section of mat slab in the middle of the excavation, and install upper tier bracing. (The base of the raker is braced against this slab.)
4. Excavate to subgrade around perimeter, and pour mat slab extending to the earth-retaining system.
5. Remove lower-tier bracing (install waterproofing), and pour lower tier wall.
6. Rebrace lower pour wall, and remove cross-lot bracing. Install waterproofing.
7. Pour upper-tier wall.

Another method is to locate the walers above an intermediate basement slab. The waterproofing is then carried up the foundation wall to the bottom of the waler, and the slab is cast against it. The waler is then removed, and the waterproofing is continued.

The above strategies should be reviewed when the excavation contractors are interviewed. Waiting until the prewaterproofing conference may be too late.

SUMMARY
Maintaining continuity of waterproofing is critical when it is penetrated by permanent and temporary components of the earth-retaining system. Prudent waterproofing designers should get involved early in the process of selecting excavation contractors to minimize problems that arise from the support of excavation systems. They should acquire SOE drawings prior to detailing the membrane to make certain that all conditions have been addressed and to ensure that the watertight integrity of the waterproofing membrane is maintained.